(2)

US Army Corps of Engineers

FIELD VERIFICATION PROGRAM

TECHNICAL REPORT D-88-[illegible]

SUMMARY OF THE US ARMY CORPS OF ENGINEERS/US ENVIRONMENTAL PROTECTION AGENCY FIELD VERIFICATION PROGRAM

by

Richard K. Peddicord

Battelle Ocean Sciences
397 Washington Street
Duxbury, Massachusetts 02332

US ARMY ENGINEER WATERWAYS EXPERIMENT STATION

October 1988

Final Report

[illegible] DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC [illegible]

US Environmental [illegible]
Washington [illegible]

[illegible] Environmental [illegible]
[illegible] Engineer Waterways [illegible]
[illegible]

ENVIRONMENTAL LABORATORY

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE

AD-A200 172

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION
Unclassified

1b. RESTRICTIVE MARKINGS

2a. SECURITY CLASSIFICATION AUTHORITY

2b. DECLASSIFICATION/DOWNGRADING SCHEDULE

3. DISTRIBUTION/AVAILABILITY OF REPORT
Approved for public release; distribution unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S)

5. MONITORING ORGANIZATION REPORT NUMBER(S)
Technical Report D-88-6

6a. NAME OF PERFORMING ORGANIZATION
Battelle Ocean Sciences

6b. OFFICE SYMBOL *(If applicable)*

7a. NAME OF MONITORING ORGANIZATION
USAEWES
Environmental Laboratory

6c. ADDRESS *(City, State, and ZIP Code)*
397 Washington Street
Duxbury, MA 02332

7b. ADDRESS *(City, State, and ZIP Code)*
PO Box 631
Vicksburg, MS 39181-0631

8a. NAME OF FUNDING/SPONSORING ORGANIZATION
See reverse.

8b. OFFICE SYMBOL *(If applicable)*

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c. ADDRESS *(City, State, and ZIP Code)*
Washington, DC 20314-1000;
Washington, DC 20460

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.

11. TITLE *(Include Security Classification)*
Summary of the US Army Corps of Engineers/US Environmental Protection Agency Field Verification Program

12. PERSONAL AUTHOR(S)
Peddicord, Richard K.

13a. TYPE OF REPORT
Final report

13b. TIME COVERED
FROM ________ TO ______

14. DATE OF REPORT *(Year, Month, Day)*
October 1988

15. PAGE COUNT
56

16. SUPPLEMENTARY NOTATION
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS *(Continue on reverse if necessary and identify by block number)*
Black Rock Harbor
Contaminants
Disposal alternatives
Dredged material
Field verification
Laboratory testing

19. ABSTRACT *(Continue on reverse if necessary and identify by block number)*

The US Army Corps of Engineers/US Environmental Protection Agency Field Verification Program was a 6-year, $7.2 million study of upland disposal, wetland creation, and aquatic disposal with dredged material. The program was designed to determine (a) the reproducibility of test methods in the laboratory, (b) the ability of laboratory test methods to predict effects in the field, and (c) the comparative effects of the same material in upland, wetland, and aquatic environments.

The program demonstrated that effluent and surface water quality prediction methods have good utility for predisposal evaluation of dredged material proposed for upland disposal. Methods for testing toxicity and bioaccumulation in wetland plants showed good predictive ability. However, optimum utility for predictive evaluations of the upland and wetland animal bioassays awaits further confirmation of the reproducibility of the test

(Continued)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION
Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL

22b. TELEPHONE *(Include Area Code)*

22c. OFFICE SYMBOL

8a. NAME OF FUNDING/SPONSORING ORGANIZATION (Continued).

US Army Corps of Engineers;
US Environmental Protection Agency

19. ABSTRACT (Continued).

results in the laboratory. Methods with good utility for evaluating dredged material proposed for aquatic disposal include toxicity, bioaccumulation, intrinsic rate of population growth, and scope for growth.

Upland disposal produced the greatest and most persistent impacts. Wetland creation produced considerably less impact, and aquatic disposal gave relatively minor and nonpersistent impacts. This is in keeping with the physicochemical behavior of dredged material in these different environments. A similar ranking of effects would be expected in the disposal of other contaminated estuarine dredged material.

[illegible] materials; [illegible] pollution;
waste management; environmental impact; (KR)

A-1

SUMMARY

The Interagency Field Verification of Testing and Predictive Methodologies for Dredged Material Disposal Alternatives, referred to as the Field Verification Program (FVP), was designed to evaluate methods for predictive evaluation of dredged material disposal alternatives. The FVP was a 6-year, $7.2 million comprehensive evaluation and comparison of environmental effects of highly contaminated dredged material placed in upland, wetland, and aquatic environments. The program was jointly supported and conducted by the US Army Corps of Engineers (CE) and the US Environmental Protection Agency (EPA).

Samples of sediment for use in laboratory studies were collected from the industrialized Black Rock Harbor Channel in Bridgeport, CT, prior to dredging. The channel was then dredged, and portions of the material were placed in an upland disposal site, used to create a wetland, and placed in an aquatic disposal site. Predictive studies were conducted in the laboratory, and the results were compared with the results of the same techniques applied in the field after disposal. This provided a basis for determining (a) the reproducibility of the test using dredged material in the laboratory, (b) the ability of the laboratory test methods to predict effects in the field, and (c) the comparative effects of the same contaminated dredged material in upland, wetland, and aquatic environments. The test methods evaluated had been developed by the CE, the EPA, and the European Economic Commission under other programs. However, in many cases, the test methods had not been applied to dredged material and had not been evaluated for predictive accuracy.

Results showed that laboratory methods for predicting effluent and surface water quality and plant toxicity in upland disposal sites compared well with field data. The techniques for predicting effluent and surface water quality were shown to have good utility for predisposal evaluations of dredged material proposed for upland disposal. Methods for testing toxicity and bioaccumulation in plants in the wetland environment showed good predictive ability. However, optimum utility for predictive evaluations for the animal bioassays awaits further confirmation of their reproducibility. Techniques shown to have good utility for predisposal evaluation of dredged material proposed for aquatic disposal include toxicity, bioaccumulation, intrinsic rate of population increase, and scope for growth.

More methods for testing chronic, sublethal effects were evaluated in the aquatic environment than in the upland or wetland environments. Methods for predicting aquatic impacts were shown to have good utility for predisposal evaluations. In general, the effects of aquatic disposal predicted in the laboratory and observed in the field were less persistent than in the other two environments. Wetland creation showed greater effects than aquatic disposal. Upland disposal produced the greatest and most persistent impacts. This is compatible with expectations based on the physicochemical behavior of contaminated dredged material in the three environments. The same ranking of effects in the upland, wetland, and aquatic environments can be expected in similar situations although the relative magnitude of effects may be different.

PREFACE

This report summarizes the US Army Corps of Engineers/US Environmental Protection Agency (USACE/USEPA) Interagency Field Verification of Testing and Predictive Methodologies for Dredged Material Disposal Alternatives Program (Field Verification Program (FVP)). The FVP was sponsored by the Headquarters, USACE, and was assigned to the US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. The objective of this interagency program was to field verify existing techniques for predicting the environmental consequences of dredged material disposal under aquatic, wetland, and upland conditions. The aquatic portion of the FVP was conducted by the USEPA, Environmental Research Laboratory, Narragansett, RI, with the wetland and upland portions conducted by the WES.

This report was prepared by Dr. Richard K. Peddicord, Battelle Ocean Sciences, New England Marine Research Laboratory. The work was conducted under the direct WES management of Dr. Thomas M. Dillon and under the general management of Dr. C. Richard Lee, Chief, Contaminant Mobility and Regulatory Criteria Group; Mr. Donald L. Robey, Chief, Ecosystem Research and Simulation Division; and Dr. John Harrison, Chief, Environmental Laboratory. Manager of the Environmental Effects of Dredging Programs was Dr. Robert M. Engler; Mr. Robert L. Lazor was FVP Coordinator. Dr. Thomas D. Wright was the WES Technical Coordinator for the FVP reports. This report was edited by Mr. Bobby Odom of the WES Information Technology Laboratory.

The USACE Technical Monitors were Drs. Robert J. Pierce and William L. Klesch. The Dredging Division, USACE, Technical Monitor was Mr. Charles W. Hummer.

COL Dwayne G. Lee, EN, was the Commander and Director of WES. Dr. Robert W. Whalin was Technical Director.

This report should be cited as follows:

Peddicord, Richard K. 1988. "Summary of the US Army Corps of Engineers/US Environmental Protection Agency Field Verification Program," Technical Report D-88-6, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

CONTENTS

SUMMARY OF THE US ARMY CORPS OF ENGINEERS/US ENVIRONMENTAL PROTECTION AGENCY FIELD VERIFICATION PROGRAM

PART I: INTRODUCTION

Perspective on This Report

1. In January 1982, the US Army Corps of Engineers (CE) and the US Environmental Protection Agency (EPA) initiated the Interagency Field Verification of Testing and Predictive Methodologies for Dredged Material Disposal Alternatives, referred to as the Field Verification Program (FVP). The FVP was designed to meet both agencies' needs to (a) document the effects of placement of the same contaminated dredged material in upland, wetland, and aquatic environments, (b) verify the predictive accuracy of evaluative techniques now in use, and (c) provide a basis for determining the degree to which biological response is correlated with bioaccumulation of key contaminants in the species under study.

2. This report is a summary of the findings of the 6-year, $7.2 million FVP. This synthesis document is a programmatic overview intended for a broad audience with different degrees of technical background. Readers desiring more detailed discussions of particular topics are referred to the upland, wetland, and aquatic synthesis reports, which are the basis for this summary report. Because the synthesis reports have been used so extensively in preparing this report, they are not cited repetitiously throughout the text. Rather, the reader is informed at this point that, unless otherwise cited, information in this report pertaining to the dredging operation, construction of the upland and wetland sites, and studies of upland disposal is contained in FVP upland disposal synthesis report (Folsom et al., in preparation). Information on studies related to wetland creation with the FVP dredged material can be found in the wetland synthesis report (Simmers et al., in preparation), and discussions of aquatic disposal studies are based on the synthesis report by Gentile et al. (1988). Specific studies comprising the program are referred to the several dozen technical reports that are the foundation of the program documentation. The technical reports are cited in the synthesis reports and are listed in Appendix A to this summary report.

Terminology

3. Upland and aquatic disposal and wetland creation with dredged material are commonly described by a plethora of imprecise, overlapping, and confusing terms. The terms "upland disposal," "wetland creation," and "aquatic disposal" have been carefully chosen for use in the FVP in order to convey the essential physicochemical characteristics that create potentials for different impacts of disposal in the three environmental conditions. Prior to dredging, sediments are saturated with water, anoxic below a thin surface layer, and near neutral in pH. The extent to which physicochemical changes in dredged material characteristics take place in various disposal environments is the major factor controlling the potential for contaminant-related impacts of dredged material in the ecosystem (Francingues et al. 1985; Saucier et al. 1978).

4. The term "upland disposal" refers to placement of dredged material, usually within a dike and away from tidal influence or adjacent waters. In such conditions, the material will dry over time and take on characteristics typical of upland soils. The essential physicochemical characteristics of upland disposal are related to the drying and oxidizing of the dredged material that occurs with time. The result can often be a substantial increase in acidity, both from acid rainfall and the oxidation of sulfides and organic material in the dredged material. The acidity can increase the environmental mobility and potential release of metals in the dredged material. The biological availability of organic contaminants can also be affected. The humic materials with which they associate are more rapidly oxidized with time. Likewise, some organics may be lost through volatilization. Biologically, dredged material disposed in an upland environment tends to be colonized in time by terrestrial plants and soil invertebrates, which are very different from the organisms that might have lived in the sediment prior to dredging or that might recolonize the dredged material if it were disposed in the aquatic environment. Major areas of environmental concern with upland disposal include effluent quality, surface runoff quality, leachate quality, and lethal and sublethal effects on colonizing plants and animals (Francingues et al. 1985).

5. Aquatic disposal refers to placement of dredged material within a body of water so that it is always covered with water. Disposal in the

aquatic environment causes less change in the physicochemical characteristics of the material than would upland disposal of the same material. This is because the sediment is simply being relocated from one aquatic environment to another. In aquatic disposal the dredged material remains saturated with water, anoxic beneath the sediment surface layer, and near neutral in pH. Thus, the factors contributing to the release of metals and organic contaminants remain relatively unchanged from the predredging situation. The organisms that colonize aquatic dredged material disposal sites are typical aquatic organisms. Major topics of environmental concern with aquatic disposal include water column impacts during and shortly after disposal, lethal and sublethal effects on colonizing animals, and bioaccumulation (Francingues et al. 1985).

6. Wetland creation with dredged material refers to the placement of material under such conditions that after consolidation, the surface is alternately covered and uncovered with water but is never exposed long enough to dry and take on typical upland or terrestrial soil characteristics. Physicochemically, dredged material used in wetland creation remains saturated with water, anoxic below the surface layer and close to neutral in pH. In other words, wetland creation is physicochemically more similar to aquatic disposal than upland disposal. Wetland creation sites tend to be colonized by aquatic organisms adapted to an intertidal existence and by typical wetland plants. These plants may or may not be the same species that would colonize nearby upland disposal sites. Major topics of environmental concern with wetland creation include effluent quality, surface runoff quality, leachate quality, and other effects including toxicity and bioaccumulation on colonizing plants and animals.

Background on the FVP

7. Section 404 of the Clean Water Act and Section 103 of the Marine Protection, Research and Sanctuaries Act require that environmental evaluations of dredged material discharges include the effects of disposal on pollutant "concentration through biological processes" (bioaccumulation), "transfer through biological processes" (biomagnification), "effects on fish, shellfish, wildlife, shores and beaches," "species and community population changes," and "other locations and methods of disposal including land-based

alternatives." In the past, some of these evaluations have been made using first-generation techniques which may or may not have been field verified and, therefore, are not universally accepted. Other evaluations, such as effect on wildlife, shores and beaches, transfer through biological processes, species changes, and alternative disposal methods, have sometimes been addressed only in a rather cursory and subjective manner because no objective evaluative procedures have been documented or verified. In order to fulfill regulatory requirements, documented and verified procedures for all the required evaluations are necessary. These procedures must be accompanied by interpretive guidance based on documented evidence in order to satisfactorily meet regulatory needs.

8. In many research programs, the CE and EPA have conducted and will continue to conduct the essential first steps of research and development of theoretically sound and practical evaluative techniques. Acceptance by other regulatory and resource agencies of those techniques that have been developed requires documentation and verification under field conditions of both the accuracy of the techniques and the overall environmental consequences of the predicted changes. The FVP was designed to meet this need. The FVP was a cooperative effort between the CE and EPA designed to provide regulatory personnel with verified procedures and interpretive guidance for use in assessing the environmental consequences of dredged material disposal under upland, wetland, and aquatic conditions. The US Army Engineer Waterways Experiment Station (WES) was the lead CE laboratory and was responsible for conducting the wetland and upland portions of the program. EPA's Environmental Research Laboratory at Narragansett, Rhode Island (ERLN), carried out the aquatic portion of the program. The US Army Engineer Division, New England, was responsible for site selection and construction of the upland and wetland disposal alternative as well as for the actual dredging and disposal operations.

Program objectives

9. The objective of the FVP was to document and verify existing and new predictive techniques for use by regulatory personnel in evaluating the long-term effects of dredged material disposal. To accomplish the program objective, evaluation techniques developed by the CE, EPA, and others were applied to project conditions using dredged material from a single maintenance dredged operation in Black Rock Harbor, Bridgeport, Connecticut. Portions of the

dredged material were placed in typical aquatic and upland disposal sites and used for wetland creation. This provided the technical opportunity of both verifying predictive evaluation procedures and directly comparing the environmental consequences of the same material under three frequently used disposal conditions. The Black Rock Harbor (BRH) dredging project was chosen for the program because the material to be dredged was in an industrial area and was known to contain a variety of contaminants. Although the material was not considered to pose an unacceptable potential for adverse environmental effects, it was considered sufficiently contaminated to rigorously test the evaluation methods and to allow comparison of effects in upland, wetland, and aquatic environments.

Program structure

10. Studies of each of the three major disposal environments included both laboratory documentation of the applicability and reproducibility of the technique(s) and verification of the accuracy of the laboratory tests in predicting environmental consequences in the field. Techniques for assessing the potential effects of aquatic disposal were much more advanced and numerous than those available for upland and wetland evaluations. Consequently, there is a programmatic emphasis toward the aquatic environment. Studies of aquatic disposal documented the laboratory accuracy and reproducibility of available procedures for predicting bioaccumulation and verified the accuracy of the predictions under field conditions. Selected physiological response parameters were evaluated in the laboratory and the field as potential indicators of the biological consequences of bioaccumulation. These parameters were developed by EPA for evaluating effects of individual environmental contaminants and sewage sludge on fish and shellfish. Studies of upland disposal documented and verified techniques for prediction of water quality effects of these activities. Plant bioassay procedures to predict toxicity and movement of contaminants into upland and wetland plants were documented and verified. Procedures to predict toxicity and bioaccumulation of contaminants in upland and wetland animals were also documented and verified.

PART II: SEDIMENT COLLECTION AND CHARACTERIZATION

Collection

11. Before dredging of the BRH channel began, sediment samples were collected with a large box-corer from 25 locations along the channel from the mouth of the harbor to the end of Federal maintenance of the navigation channel. The boat was positioned above the desired location, and the box-corer was lowered by cable and allowed to penetrate the sediment (generally 0.5 to 1.0 m). The box-corer was lifted out of the water and positioned over a washed 208-ℓ (55-gal) steel drum; the bottom of the corer was opened, and the sediment in the corer was allowed to drop into the drum. Two samples at each location were sufficient to fill a drum. After each drum was completely filled with sediment, it was sealed and placed in a refrigerated truck at 4° C for transportation to WES.

12. Upon arrival at WES, the sediment from all 25 drums was composited into one homogenous sample (Folsom and Lee 1982), which was then subdivided among the researchers so that upland, wetland, and aquatic laboratory studies were performed with the same sediment. The sediment was mixed in a large cement truck that had been cleaned by extended tumbling with clean sand and gravel, steam cleaning, and thorough rinsing. Immediately before the sediment was placed in the mixer, air was displaced from inside the mixer with nitrogen gas. The contents of all 25 drums were emptied into the truck and mixed for 30 min. The composited material was then poured back into washed drums. The drums were sealed, refrigerated at 4° C, and distributed to the appropriate investigators for study. The composited dredged material samples were maintained at 4° C until used in laboratory studies.

Characterization

13. Sediment from Black Rock Harbor is regarded as highly contaminated. This dredged material contains substantial amounts of polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB), and heavy metals. Selected sediment parameters are given below. More complete and detailed chemical analysis can be found in Rogerson, Schimmel, and Hoffman (1985).

Parameter	Content
Organic matter	19.5%
Salinity	28.0 ppt
pH, wet	7.6
Phenanthrene	5.0 μg/g dry
Fluoranthene	6.3 μg/g dry
Benzo(a)pyrene	3.9 μg/g dry
Sum of PAHs	142.0 μg/g dry
PCB as A1254	6.4 μg/g dry
Cadmium	24.0 μg/g dry
Chromium	1,480.0 μg/g dry
Copper	2,900.0 μg/g dry
Iron	31,000.0 μg/g dry

PART III: SITE CONSTRUCTION

Field Study Requirements

14. The FVP upland, wetland, and aquatic sites had to meet specific design, construction, operation, and management requirements for various portions of the study. These requirements included the following:

- a. Dredged material placed in the upland, wetland and aquatic sites had to be similar to ensure valid comparison of results.
- b. Dredged material had to be hydraulically placed within the upland and wetland sites in a manner normally used for confined disposal.
- c. Aquatic disposal had to be at a discrete point and could be by mechanical or hydraulic means. The mechanical operation chosen was typical of clamshell dredging operations commonly employed.
- d. A minimum thickness of dredged material of 1 m (3 ft) had to be achieved in both upland and wetland sites following sedimentation and consolidation.
- e. Surface elevations following sedimentation and initial consolidation had to be at least 1 m (3 ft) above mean high water elevation for the upland site and within the intertidal range for the wetland site.

Site Selection and Design

Site selection

15. Acceptable sites for upland and aquatic disposal and for wetland creation were difficult to locate because the FVP used contaminated dredged material from a highly industrialized coastal area. Several potential upland and wetland sites were extensively studied, and preliminary designs and cost estimates were prepared. However, all sites were ultimately rejected because of cost or real estate considerations. The site holding the best potential from a real estate and cost standpoint, and the site ultimately selected, was located at Tongue Point, Connecticut, about 8.3 km (4.3 nautical miles) from the BRH channel (Figure 1).

16. Exact locations for the FVP upland and wetland sites were chosen in consultation with interested state and Federal agencies and the property owner. Separated upland and wetland sites were chosen to ease construction and management. The final size and orientation of the sites were based on

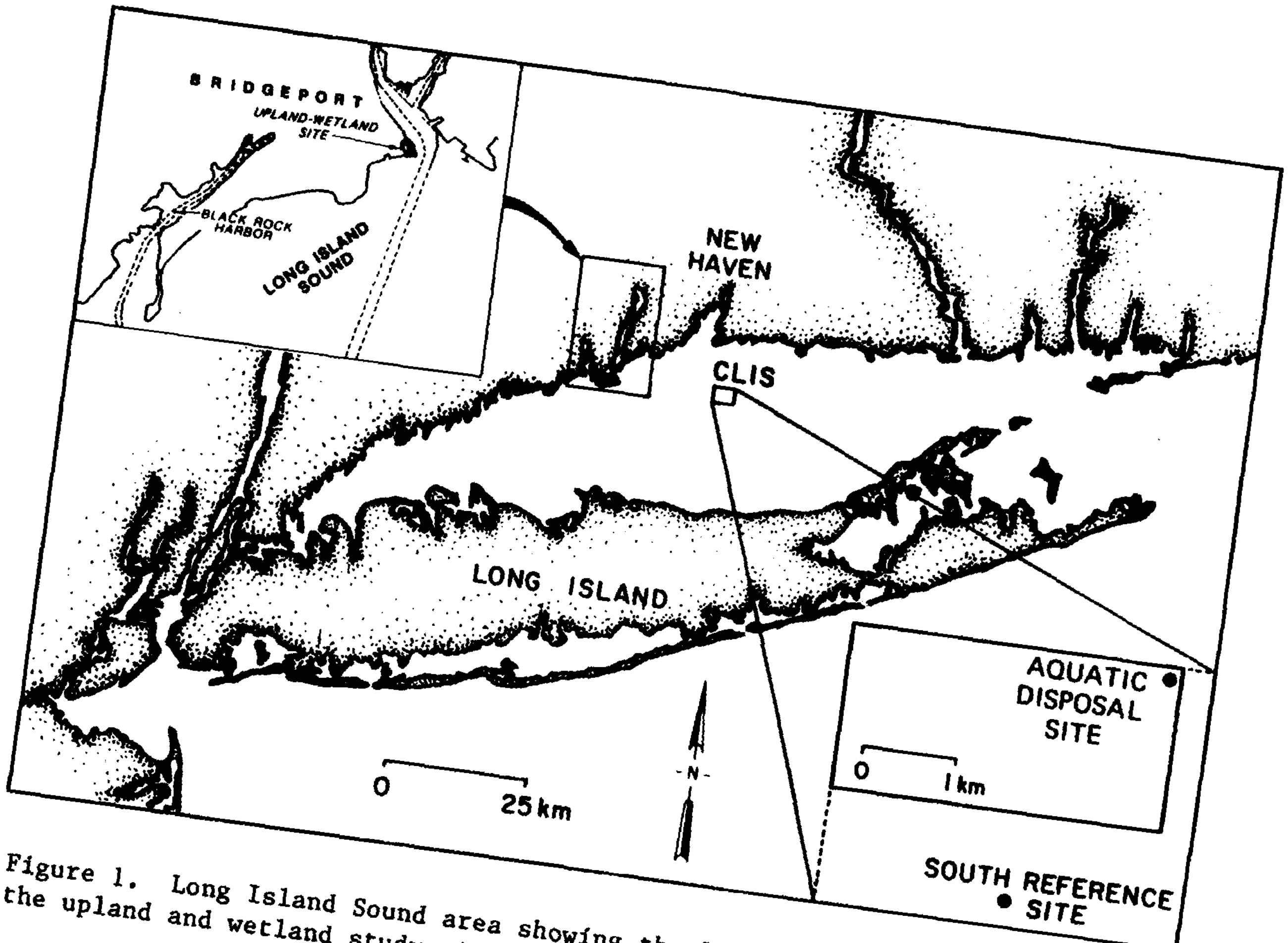

Figure 1. Long Island Sound area showing the location of Black Rock Harbor, the upland and wetland study sites at Bridgeport, and the aquatic study site at the CLIS disposal area

minimum study requirements, site designs, existing topography, and tidal flow within the enclosed area.

17. To meet the FVP program objectives, it was important that the aquatic disposal take place at a nondispersive site to reduce the potential for impacts beyond the immediate study area. The Central Long Island Sound (CLIS) disposal site (Figure 1) was selected because it had been studied since 1974 and continuously monitored since 1979. Also, the water and sediments of the central sound were less contaminated than at the other candidate sites in the western sound where the influence of the East River and the intense industrialization combined with more restricted circulation to increase the contaminant loading.

18. The specific location within the CLIS for the FVP aquatic disposal operation was selected to:

a. Reduce the potential for adverse environmental impact,

b. Minimize interaction or interference with FVP studies by material from past or future disposal operations, and

c. Minimize background variability in topography, sediment chemistry, grain size, and benthic community characteristics.

19. In order to meet these criteria, the disposal point had to be located as far as possible from previous and ongoing disposal operations yet at sufficient distance from the margins of the site to ensure minimal spreading of dredged material beyond the boundaries of the designated disposal site. Because most of the recent disposal had taken place in the southwest corner of the CLIS site, the northeast quadrant was selected as the most favorable quadrant for disposal of dredged material for FVP studies (see inset in Figure 1).

Site design

20. Preconstruction evaluations of storage capacity and sedimentation characteristics in the upland and wetland sites were necessary to design the sites to achieve effective settling during disposal and to obtain the desired ultimate configuration on the substrate in each site.

21. The available surface areas for the sites were limited; therefore, the major effort or concern of the sedimentation design was to match a maximum allowable filling rate to the available volume for temporary holding or ponding of water within the site to allow settling of suspended solids before the water was discharged. Procedures found in Palermo, Montgomery, and Poindexter (1978) and Palermo (1985) were followed for the designs. Results from sedimentation tests with composited BRH dredged material indicated that the available ponding for the sites could maintain effective settling for a maximum flow rate into the site of approximately 28.3 ℓ/sec (1 cu ft/sec). Data from Palermo, Montgomery, and Poindexter (1978) were used to select required crest lengths for the weir or discharge regulation structure to pass the flow during filling without resuspending settled material. A weir length of 1.2 m (4 ft) was selected for the wetland site, and two 1.2-m weirs were selected for the upland site.

22. Settling test results were used to determine the volume required for initial storage during dredging. Minimum freeboard and ponding requirements and available surface areas were then considered in setting required dike crest elevations and bottom grades for both the upland and wetland sites. In the upland site, the dike crown elevation was +4.3 m (14.0 ft) above mean

low water (mlw) and the bottom grade was 2.1 m (+7.0 ft) mlw. In the wetland site, the dike crown elevation and bottom grade were +2.7 and +0.9 m (9.0 and 3.0 ft), respectively.

23. The final desired substrate elevation for the dredged material in the upland site was +2.7 m (8.7 ft) mlw or greater. The final desired substrate elevation for the wetland was +1.7 m (5.5 ft) mlw, slightly below the mean high tide elevation. Results from the consolidation tests indicated that approximately 2,294 cu m (3,000 cu yd) of in situ channel material had to be placed in the upland site to achieve the desired final substrate elevation. Approximately 765 cu m (1,000 cu yd) of dredged material were required to construct the wetland.

24. At the location within the CLIS disposal site selected for the FVP aquatic disposal studies, the bottom had a gentle slope toward the south with a depth difference of 1 m (3.3 ft) over the disposal survey area. The bottom at the site was generally a fine silt. Mud furrows oriented parallel to the direction of the tidal flow were present in the south and east portions of the survey area and near the buoy moored to indicate the exact point where the dredged material was to be dumped from the barge.

Upland and Wetland Site Construction

25. All grading and dike construction for the upland and wetland sites were performed by conventional construction equipment (Figure 2). Only minimum bottom grading was required in the upland site. An area immediately around the weir was sloped downward to el +1.5 m (5.0 ft) to ensure a drainage gradient toward the weir that helps management of the site. Dikes for the upland site were constructed with material excavated from the wetland site and an adjacent area. Total surface area was approximately 2,583 m^2 (27,800 ft^2). Weir structures consisted of 1.2-m (4-ft) diameter drop inlets welded to base plates and ballasted to prevent uplifting during filling operations. The weirs had adjustable risers of various sizes to finely adjust overflow if required.

26. Settlement plates and observation wells were installed during construction. Settlement plates consisting of vertical risers marked at 7-cm (0.2-ft) intervals were placed in both sites to monitor consolidation of the fills. Observation wells were installed in the center and along the outside

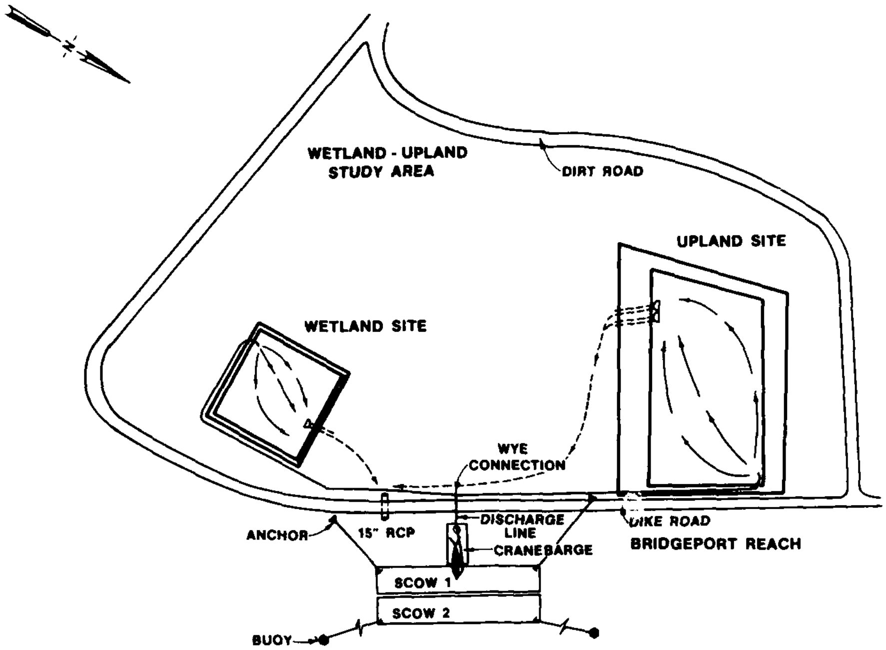

Figure 2. Site plan for Tongue Point Study area

of each dike segment in the upland site to monitor ground water before and after filling.

27. The wetland construction involved excavation of foundation material to the elevations required to achieve a lower bottom grade, accommodating the required dredged material thickness and still allowing the surface elevation to remain within the intertidal range. Along one side of the site, a sandbag dike was constructed that could be removed after filling to provide easy tidal interchange. Final total surface area of the wetland was approximately 706 m^2 (7,600 ft^2).

Dredging and Disposal

28. Because the available sites for upland, wetland, and aquatic studies were located away from the BRH channel, transportation and off-loading of the material from barges were required. Material for the FVP aquatic studies was removed by clamshell dredge from a strip along the entire length of the study reach. The remaining undredged strip of the channel was later used for acquiring the upland/wetland material, meeting the requirement that

the same sediment be used for upland, wetland, and aquatic sites. As the upland/wetland sites were readied to receive the material, a 9.9-m^3 (13-yd^3) clamshell dredge excavated approximately 4,588 m^3 (6,000 yd^3) from the channel and placed the material into two 3,058-m^3 (4,000-yd^3) capacity barges. The dredging operation was accomplished within 24 hr. During the dredging, the clamshell bucket easily penetrated the material, removing full cuts at their in situ density so that the material in the filled barges was essentially in its in-channel condition. The filled barges were then transported to a mooring barge located adjacent to the upland and wetland sites.

29. The upland and wetland sites were filled with BRH sediment during the last part of October 1983. The material in the barges was slurried and pumped out to meet the study requirement that the material be hydraulically placed in the sites in a manner typical of upland dredged material disposal or wetland construction. During initial pumping, several intakes and equipment combinations were tried. A pump combination consisting of a 15.2-cm (6-in.) submersible pump, a 15.2-cm (6-in.) booster pump, and an attached 7.62-cm (3-in.) jet pump for adding slurry water was finally selected. A crane was used to manipulate the intake within the barges. A 15.2-cm (6-in.) dredge pipe, equipped with a Y-valve, split the dredged material inflow between the upland and wetland sites. During the filling, the flow was proportioned between the sites according to their respective volumes, ensuring that essentially similar dredged material was placed in both sites.

30. During the filling period, the concentration of the inflow slurry solids ranged from 50 to 100 g/ℓ with a mean of approximately 61 g/ℓ. Intermittent pumping was used to maintain the flow rate at the maximum allowable 0.028 m^3 (1 ft^3) per second. The filling was completed within a 13-day period. The mean concentration of suspended solids in the effluent was approximately 173 mg/ℓ. The site had a solids retention efficiency of 99.7 percent indicating that the minimum flow rate as determined from the sedimentation design was adequate for the ponding area available.

31. Solids concentration and accumulated depth of slurry were measured periodically during the filling operation to monitor the material volume and density. The filling was stopped when volumes and densities in both upland and wetland indicated that, after consolidation, the substrate surfaces would be at the desired elevations.

32. Dredged material for the aquatic studies was removed from the Black Rock Channel by the clamshell dredge and point-dumped from barges at a disposal buoy marking the center of the selected disposal location.

33. On 28 April 1983, an interim bathymetric survey was conducted to assess the conditions of the site as the first barge loads of dredged material were deposited. This survey indicated that a small mound had formed near the disposal buoy, and that additional disposal should create the desired mound.

34. Following completion of the FVP disposal operation, a postdisposal baseline survey was conducted on 19 May 1983. This survey indicated that approximately 55,000 m^3 (42,000 yd^3) of material, measured by barge displacement, had formed a small elliptical mound slightly less than 200 m (656 ft) in diameter and slightly more than 2 m (6.6 ft) thick (Figure 3).

35. Sediment samples taken after completion of the survey indicated the presence of BRH dredged material at distances of less than 400 m (1,310 ft) in the north-south direction, a trace of BRH dredged material 400 m (1,310 ft) east of the mound, and substantial covering with BRH material 400 m (1,310 ft) west of the mound. At distances less than 400 m (1,310 ft) from the site,

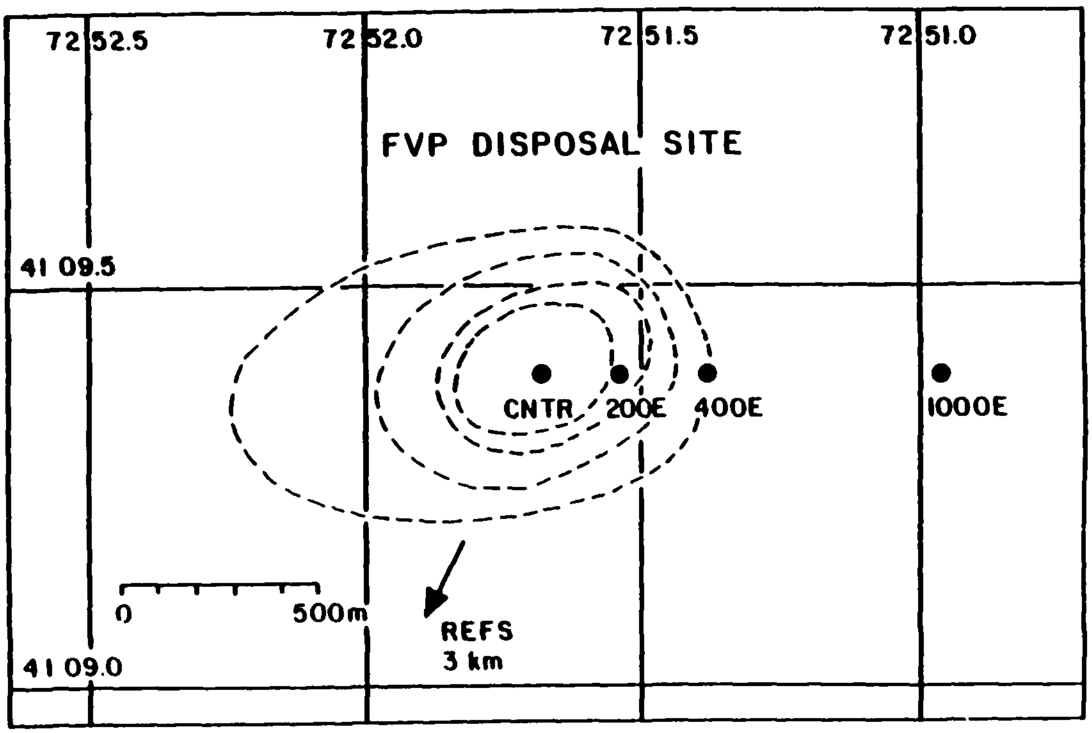

Figure 3. FVP disposal site and station locations

black organic silt from BRH was present with thicknesses varying up to 5 cm (2 in.) at distances of 200 (656 ft) to 300 m (984 ft) (Morton 1983).

Upland and Wetland Site Management

36. Following the filling in October 1982, the ponded water was decanted from the upland site by removing weir boards. Ponded water was left standing in the small depression designed immediately in front of the weir preventing erosion of the freshly settled material through surface water runoff. Because the sites were filled in late October, only the initial stages of consolidation and stabilization took place prior to winter freezing of surface water. Following the thaw, ponded water was again able to drain from the surface, and weir boards were removed as consolidation progressed. By August 1984, the upland site had developed a dried surface crust approximately 20.32 cm (8 in.) thick in the area near where the inlet pipe had been located. By late August 1984, consolidation had produced an average surface elevation of approximately +2.9 m (9.6 ft) mlw, well above the minimum required elevation of +2.7 m (8.7 ft) mlw.

37. Weir boards were lowered in the wetland site following the filling operation as consolidation of the fill progressed. This allowed an interchange of tidal flow through the weir structure. The sandbag dike was not breached during the initial stages of fill consolidation to ensure minimal erosion of the dredged material. By late August 1984, consolidation had produced the desired average surface elevation of +1.7 m (5.5 ft) mlw.

PART IV: UPLAND DISPOSAL: SUMMARY

Introduction

38. Laboratory and field studies of BRH dredged material under conditions typical of upland disposal involved a number of evaluative procedures developed by the CE in other programs. The major studies involved techniques for predicting or evaluating:

- a. Effluent quality during site filling.
- b. Quality of surface water runoff after site filling.
- c. Ground water quality associated with the site.
- d. Contaminant mobility into plants colonizing the site after filling.
- e. Contaminant mobility into soil invertebrates colonizing the site after filling.

39. A primary goal of all the upland studies was to provide techniques for evaluating the potential for contaminant-related impacts in the long term; that is, sufficiently long after disposal that the dredged material has dried and oxidized, has reached physicochemical conditions typical of upland disposal sites, and typical upland plants and invertebrates have become established on the site.

Effluent Quality

40. The prediction of the quality of effluent from confined dredged material disposal areas must account for both the concentration of dissolved contaminants and that fraction of the contaminants associated with the total suspended solids. A modified elutriate procedure (Palermo 1985) was used for laboratory predictions of effluent water quality. This test determines concentrations of dissolved and particle-associated contaminants under quiescent settling conditions and considers the major physicochemical changes that occur in typical upland disposal sites during disposal operations. A column-settling test procedure (Palermo, Montgomery, and Poindexter 1978) was used to predict suspended solids concentration of the effluent for the given operational conditions.

41. The column-settling analysis and corresponding prediction of effluent suspended solids concentration compared favorably with the field data, slightly overestimating the effluent suspended solids. The mean suspended solids concentration in the effluent was approximately 173 mg/ℓ. Suspended solids data collected in the effluent during disposal demonstrated that the site had a solids retention efficiency of 99.7 percent indicating that the minimum flow rate as determined from the sedimentation design was adequate for the ponding area available. The modified elutriate test adequately predicted the concentrations of dissolved and particle-associated contaminants in the effluent. Comparison of laboratory test results with field data indicated that the modified elutriate test generally overpredicted contaminant concentration in the effluent from the field site. The relative retention of contaminants within the site was high because most contaminants were directly associated with particles.

42. The effect of retention and ponding on physicochemical parameters was varied. Dissolved oxygen (DO) concentrations in the effluent showed marked increases compared to influent DO concentrations due to turbulence, mixing, and atmospheric reaeration in the water ponded within the site. The high effluent DO concentrations confirmed that oxidizing conditions were present in the ponded waters in the disposal area. The average total metal concentrations in the effluent were much lower than the average influent concentrations, reflecting a high removal due to sedimentation in the disposal area. Results for total phosphorus, total organic carbon, and PCB removal were similar to those for metal removal. The EPA Maximum Water Quality Criteria for Protection of Aquatic Life were, however, exceeded in the effluent by dissolved copper, nickel, and PCB.

Surface Runoff

43. Results of the tests conducted in the laboratory to evaluate the quality of surface runoff from a wet unconsolidated slurry of BRH sediment typical of newly filled upland disposal sites (Lee and Skogerboe 1984) showed that contaminants were poorly soluble and tightly bound to the particulates. Laboratory tests predicted that total or unfiltered concentrations of heavy metals in surface runoff from the field site would be high. When the BRH sediment was allowed to dry and oxidize, as occurs over time in a typical upland

disposal site, important physicochemical changes occurred that increased the solubility of some of the contaminants. Dissolved concentrations of cadmium, copper, manganese, nickel, and zinc were high in surface runoff from the dry, oxidized BRH sediment. When the surface runoff water quality test was conducted on BRH dredged material in the upland site, results verified the laboratory predictions. Dissolved cadmium, copper, manganese, nickel, and zinc concentrations in the runoff water exceeded the EPA Water Quality Criteria in both the laboratory and field tests.

Ground-Water Quality

44. Predictive tests to evaluate potential impacts on ground-water quality are not routinely available and consequently were not performed as part of the FVP. However, ground-water in and around the upland site was monitored before and after the disposal operation.

45. Results of the monitoring indicated that an initial plume of PCB had migrated into the ground-water after the BRH sediment was placed into the site. However, after 14 months PCB concentrations had decreased to below detectable limits, indicating that PCB migration from the site had essentially ceased. Of the metals analyzed, only cadmium may have migrated from the site into the ground-water. Arsenic, manganese, and cadmium concentrations were above Connecticut state standards in unfiltered and filtered ground-water samples after disposal; however, arsenic and manganese concentrations were also above standards prior to disposal operations. Only cadmium appeared to continue to migrate from the site after 14 months.

Plant Toxicity and Bioaccumulation

46. The estuarine plant bioassay procedure (Folsom and Lee 1981) was used in the laboratory to evaluate the potential metal uptake by plants from composited and homogenized BRH sediment. Analysis of the bulk chemistry and chelating extractant data from composited BRH sediment conducted as part of the plant bioassay procedure indicated that the BRH sediment at the disposal site would eventually become extremely acidic and highly saline upon air-drying.

47. To get the estuarine index plants *Spartina alterniflora* and *Sporobolus virginicus* to grow in the laboratory for evaluation of plant uptake of metals, it was necessary to both rinse the BRH sediment with fresh water to reduce salinity and to apply agricultural soil amendments. These soil amendments consisted of the addition of various combinations of agricultural lime and limestone to help control soil acidity, horse manure to improve the rooting and growing medium for the vegetation and to complex soluble metals, and sand to loosen the soil and help provide an uncontaminated rooting medium for plants. Several salt-tolerant plant species were also evaluated.

48. The laboratory portion of the plant bioassay procedure substantiated the predictions based upon the chelating extractant data. Neither index plant species grew in unamended, unrinsed BRH sediment, and *S. alterniflora* would not grow even in the amended sediment. Death of *S. alterniflora* in the field site was so clearly predicted by the laboratory tests and an in situ field plant bioassay that no further attempts were made to test *S. alterniflora* in the field. Laboratory tests predicted that *S. virginicus* should grow normally in amended, rinsed BRH sediment, and that these plants would take up excessive amounts of some metals and not others. Laboratory test results predicted that concentrations of cadmium in *S. virginicus* would be elevated, and field results confirmed this prediction. Zinc, nickel, and chromium were predicted to be elevated in *S. virginicus*; field results showed, however, that they were not. Laboratory-grown *S. virginicus* indicated that copper and lead bioaccumulation would be low; field-grown plants, however, had higher copper and lead contents.

Animal Toxicity and Bioaccumulation

49. The initial earthworm bioassay conducted in the laboratory indicated that the BRH sediment was quite toxic under the physicochemical conditions typical of upland disposal. Earthworm bioassays using BRH dredged material diluted and rinsed to remove salinity did not indicate toxicity or elevated levels of heavy metals or organic contaminants in the earthworm tissue. Analysis of washed BRH dredged material indicated that concentration of metals and organic contaminants had not changed, implying that the toxicity may have been due in part, to excessive salinity. Field tests confirmed

laboratory results, indicating that the dredged material at the site was quite toxic. Because this toxicity may be due to excessive salinity, full field verification of the earthworm test will be accomplished when the salinity of the dredged material in the disposal site has been reduced by normal rainfall, and stable long-term conditions typical of upland disposal sites have been established. Bioaccumulation could not be examined because no earthworms survived in the field.

PART V: WETLAND CREATION: SUMMARY

Introduction

50. A number of procedures for evaluating potential contaminant-related impacts of wetland creation with dredged material have been developed and are being further developed under various programs. Wetland creation studies under the FVP employed some of these procedures to predict and evaluate:

a. Toxicity to wetland plants.

b. Bioaccumulation in wetland plants.

c. Toxicity to wetland animals.

d. Bioaccumulation in wetland animals.

51. A primary goal of all the wetland studies was to provide proven techniques for evaluating the potential for contaminant-related impacts in the long term; that is, sufficiently long after disposal that the dredged material has consolidated, become physicochemically stable, and typical wetland plants and animals have become established on the site.

Plant Toxicity and Bioaccumulation

52. During wetland site construction and stabilization, the estuarine plant bioassay (Folsom and Lee et al. 1981) was used in the laboratory to evaluate the potential for contaminant uptake by plants from composited and homogenized BRH sediment. Chelating extracts of the freshly composited BRH sediment were chemically analyzed as part of the plant bioassay procedure to predict plant uptake of metals (Lee, Folsom, and Bates 1983). Although the laboratory portion of the plant bioassay procedure predicted uptake of most metals reasonably well, it underpredicted concentrations of copper and overpredicted chromium concentrations in field-grown *S. alterniflora* (saltmarsh cordgrass). However, plant uptake of metals was relatively low and did not exceed typical concentrations observed in plant tissue in naturally occurring wetlands (Simmers et al. 1981). Previous research indicated that *S. alterniflora* does not accumulate organic contaminants; therefore, analyses for PCBs or polynuclear aromatic hydrocarbons (PAHs) were not conducted.

53. Metal concentrations in field-grown *S. alterniflora* were predicted fairly well by both the chelating extractant and the laboratory plant

bioassay. However, the laboratory bioassay did not predict that *S. virginicus* would be unable to survive in the wetland site.

Animal Toxicity and Bioaccumulation

54. A wetland animal bioassay was conducted with the composited sediment in the laboratory using an adaptation of the plant bioassay procedure and an index animal, the sandworm *Nereis virens*. The freshly collected sediment in an initial static laboratory bioassay was found to be acutely toxic to *N. virens*. A dilution study conducted with the fresh sediment in the laboratory indicated that a mixture of 25-percent BRH sediment and 75-percent clean sand would permit up to a 14-day survival of the sandworms. Chemical analysis indicated that cadmium and copper were accumulated in sandworms exposed to the diluted BRH sediment in the laboratory. PAH and PCB were not accumulated above detection limits. The laboratory bioaccumulation test underpredicted heavy metal concentrations in animals colonizing the field site but accurately predicted the low PCB and PAH tissue levels observed in sandworms in the field.

55. Subsequent to the initial laboratory static bioassay, a laboratory bioassay simulating tidal flow was conducted using the sandworm and another indigenous field species, the mud dog whelk (*Nassarius obsoletus*). In this study simulating tidal exchange, there was no toxicity, but bioaccumulation of metals, PAHs, and PCBs occurred in both species. These results predicted that there was a potential for accumulation of metals and organic contaminants in animals colonizing the wetland created with BRH dredged material. This was borne out by the field data.

PART VI: AQUATIC DISPOSAL: SUMMARY

Introduction

56. Laboratory and field studies of BRH dredged material under conditions typical of aquatic disposal involved a number of evaluative procedures developed by EPA in other programs. The major studies involved techniques for predicting and evaluating:

- a. Toxicity.
- b. Scope for growth (SFG) and bioenergetics, a measure of the net energy reserves available to an organism for growth and reproduction, over and above the energy needed for maintenance.
- c. Adenylate energy charge (AEC), a measure of available energy from a metabolic perspective.
- d. Sister chromatid exchange (SCE), a measure of the exchange of genetic material between chromatids of a chromosome during cell division.
- e. Histopathology, a microscopic examination of tissue for changes that might indicate disease or abnormalities.
- f. Population growth rate, an assessment of the demographic status of a population of organisms.
- g. Recolonization of the disposal site.
- h. Bioaccumulation.

57. A primary goal of all the aquatic studies was to verify existing techniques for evaluating the potential for contaminant-related impacts in the long term; that is, sufficiently long after disposal that perturbations associated with the disposal operation have ceased, the dredged material has consolidated and become physically and geochemically stable, and typical aquatic organisms have become established on the disposal site.

58. A primary objective of the aquatic FVP studies was to verify the predictive accuracy of laboratory biological tests by measuring the same response in the same species both in the laboratory and in the field. A basic and usually unstated assumption in environmental testing is that results derived from laboratory tests are predictive of effects to be expected in the field. The hypothesis, explicitly stated, is that there are no significant differences in the exposure-response relationships measured for the same species in the laboratory and the field. The acceptance of this hypothesis is necessary to extrapolate laboratory predictions to the field with some degree

of confidence. Testing this hypothesis requires both the determination of field exposure conditions and the reproduction of these conditions in the laboratory. Field exposure data in this study are discrete rather than continuous. Therefore, comparison between laboratory and field responses focuses on representative exposure boundaries rather than attempting to precisely mimic real-time exposure conditions. The results clearly support the hypothesis that with some biological tests, similar response patterns can be expected in the laboratory and in the field when exposure conditions are comparable.

Toxicity

59. Survival in 11 species of aquatic organisms representing four phyla was determined after exposure to deposited and suspended BRH sediment in the laboratory (Rogerson, Schimmel, and Hoffman 1985). Only the infaunal amphipod *Ampelisca abdita* showed acute mortality when exposed to deposited BRH sediment. Burrowing activity was impaired in the polychaete *Nephtys incisa* and the mollusc *Yoldia limatula*, and tube building was impaired in *A. abdita*. No acute effects were noted with epibenthic or water column species exposed to deposited BRH sediment either alone or in combination with suspensions of 25 mg/ℓ BRH sediment.

Scope for Growth and Bioenergetics

60. The results of the laboratory study indicated that the contaminant concentrations in mussels *Mytilus edulis* were indicative of exposure conditions and that the SFG index was useful for measuring the subsequent biological effects of those exposures (Nelson et al. 1986). An inverse relationship was observed in the laboratory between SFG and exposure to BRH sediment. SFG was inversely related to bioaccumulation of some of the contaminants present in the dredged material. The lower SFG values observed in BRH-exposed mussels were attributable to reduced clearance rates observed in the laboratory. In addition, mussels with lower SFG values exhibited reduced growth rates.

61. The estimated concentration of suspended BRH sediment which affected SFG in the field was similar to the effective concentration predicted from laboratory experiments. The laboratory-derived response threshold for

SFG in *M. edulis* was 1.5 mg/ℓ suspended BRH sediment. Field exposure conditions at the position of the mussels (1 m (3.28 ft) above the bottom) were generally at or below 1.5 mg/ℓ during and immediately after disposal and were even lower after more time. The field values for SFG at the disposal site stations were affected only during the disposal and immediate postdisposal period when the estimated exposures in the field reached the laboratory-derived response threshold. Thus, laboratory predictions of little effect agreed with the actual field measurements of SFC in *M. edulis*.

62. The bioenergetics' responses measured in *N. incisa* included growth, respiration, excretion, cumulative energy for production, and net growth efficiency (Johns, Gutjahr-Gobell, and Schauer 1985). Each response was directly related to the exposure to the BRH dredged material and was highly reproducible. Growth, production, and net growth efficiency were the most sensitive responses measured in *N. incisa*. Field verification, limited to excretion and respiration, correlated well with previous laboratory studies on this species.

Adenylate Energy Charge

63. The biological responses evaluated included the adenine nucleotide measures of adenosine triphosphate (ATP), adenosine diphosphate (ADP), adenosine monophosphate (AMP), adenine nucleotide pool, and AEC (Zaroogean et al. 1985). These responses were measured in *M. edulis* and *N. incisa* exposed to BRH sediment in the laboratory and in the field. The only significant laboratory response was a reduction in total adenine nucleotide pool in *M. edulis* at exposures to BRH dredged material higher than any estimated to occur in the field. Adenylate energy charge measured in *M. edulis* did not show an exposure-response relationship in the laboratory and thus would not be expected to do so in the field. The only field responses of note were station-related changes in all adenylate nucleotide concentrations measured in *N. incisa* 16 weeks after disposal. However, these changes were of minor ecological importance when viewed within the context of the total study.

Sister Chromatid Exchange

64. The current ocean dumping regulations include consideration of genotoxicity in the regulatory decision-making process. The application of SCE response to evaluating the genotoxicity of dredged material (Pesch et al. 1987) has pointed out the need for additional research in this area. There was an inconsistency in the SCE response among the laboratory replicate tests, which suggests that the application of SCE to dredged material testing with *N. incisa* needs further development.

Histopathology

65. The histopathological exposure-response relationships were difficult to quantify in a reproducible manner even under laboratory conditions (Yevich et al. 1986). The percent incidence of pathology within a specific organ system in *M. edulis* was related to exposure to BRH dredged material in the laboratory. In *N. incisa*, the only histological response detected in replicated laboratory experiments was thickening of the epidermis. Based upon laboratory data and the duration and intensity of field exposure, histological effects were not predicted to occur in the field in *M. edulis* or *N. incisa*. No effects were observed in either species in the field. One of the apparent advantages of histopathology was its expected usefulness for the field assessment of chronic impacts, so the lack of effects in the lab or field was surprising. However, histopathology was useful in providing insight into the causes (destruction of gill architecture) for the observed effects on SFG in *M. edulis*.

Population Growth Rates

66. Acute and chronic toxicity responses, including population growth rates, were related to exposure in a highly reproducible and predictable manner in both the mysid *Mysidopsis bahia* and *A. abdita* (Gentile et al. 1985). Of the responses measured, growth, reproduction, and intrinsic rates of population growth were consistently the most sensitive responses within a species as well as between these two species. The concentration of suspended BRH dredged material that reduced the intrinsic rate of population growth of

M. bahia by 50 percent was 42 mg/ℓ. A suspension of BRH dredged material of 4.5 mg/ℓ reduced the intrinsic rate of population growth of *N. incisa* by 50 percent.

67. Community responses, measured as recolonization, were examined in the field to serve as a biological benchmark for the FVP. Enumeration of species and calculation of population densities from sieved Smith-McIntyre benthic grab samples were complemented with the Remote Ecological Monitoring of the Seafloor System (REMOTS) (Scott et al. 1987). Both methods conveyed the same general patterns of spatial and temporal impact and rates of recovery. The overall impression was that impacts occurred only where BRH dredged material was present, and chat recolonization was proceeding steadily toward a return to a benthic community typical of Central Long Island Sound. The REMOTS method offered several advantages as a rapid screening tool for assessing the spatial distribution of the dredged material, for insight into the oxidation state of the seabed, and for determining stage of recolonization. It is useful for these purposes to complement more detailed characterization of the infaunal community structure by species enumeration. Because the algorithm for characterizing the community structure or organism sediment index (OSI) using REMOTS is only qualitatively described, the method cannot replace species enumeration at this time. The REMOTS method could be useful for predisposal characterization of a disposal site and for post-disposal reconnaissance. Species enumeration methods could be needed only in definitive studies where a high level of resolution is required to verify a prediction or to make a decision.

Bioaccumulation

68. Because biological response is a direct function of exposure conditions, it is important that laboratory exposures be controlled and adequately simulate field conditions. The methods developed to control exposure to suspended sediment concentrations in the laboratory achieved these objectives (Lake, Hoffman, and Schimmel 1985). The resulting contaminant bioaccumulation patterns in *M. edulis* in the laboratory were directly related to exposure to suspended BRH sediment. The concentrations of PCB in *M. edulis* tissues, when corrected for organism lipid content, were linearly related to PCB concentration in BRH dredged material. Concentrations of PCB and PAH in *M. edulis*

reached steady state within 28 days in the laboratory. After 55 days exposure in the laboratory to deposited BRH sediments, concentrations of PAH in *N. incisa* tissues reached an apparent steady state, but PCB tissue concentrations did not. After 42 days exposure to suspended BRH sediment, both PAH and PCB tissue concentrations reached an apparent steady state. Field bioaccumulation patterns in *M. edulis* paralleled laboratory studies in the types of compounds accumulated, the distribution of PCB congeners, and the quantitative values for the major contaminants. Bioaccumulation patterns in *N. incisa* in the laboratory and field showed a high degree of concurrent. PCBs were the most useful compounds for examining the relationship between bioaccumulation in *M. edulis* and *N. incisa*, which was predicted in the laboratory and was observed in the field.

69. The relationships between contaminant concentrations in tissues and the biological responses measured in the organisms were examined using correlation analysis, which does not imply cause and effect when dealing with complex wastes. As expected, the biological responses that showed an exposure-response to BRH suspended sediment concentration also showed a body-burden response relationship to contaminants that were bioaccumulated. In general, the PCBs were the most strongly correlated with the biological responses and were closely followed by the higher molecular weight PAHs. Of the metals, only copper and cadmium bioaccumulation in *M. edulis* and chromium bioconcentration in *N. incisa* were correlated with biological responses. These studies demonstrate that there is a relationship between biological responses and tissue concentrations of some contaminants that are bioaccumulated and not readily biodegraded.

PART VII: EVALUATION OF PREDICTIVE TECHNIQUES

70. From the beginning of the program, it had been clear that it would be very difficult to develop a quantitative approach for evaluating the variety of predictive techniques used in the FVP. Therefore, even though results of each technique are expressed in terms of quantitative data, the relative comparisons of the techniques were expressed by qualitative ratings of good, fair, and poor. A rating of good indicates a technique showed sufficient correspondence between tests and between the laboratory and field for most parameters to be reliably applied in routine evaluations. If the correspondence was not so good or was not consistently good for most parameters, the technique was rated fair. Poor ratings indicate little or no correspondence between tests or between laboratory and field data. Therefore, the techniques cannot be relied upon for routine applications. With further development, techniques at present considered fair or poor may become routinely applicable.

71. In the context of this document, the evaluation of the utility of a technique refers to the predictive reliability of the technique as demonstrated in the FVP. This evaluation of utility does not consider the need for the evaluation in a particular case, cost, time requirements, etc. Therefore, an indication of good utility for a particular technique cannot be taken as a suggestion that it be routinely utilized in all dredged material evaluations.

Techniques for Predicting Upland Disposal Effects

Upland site design

72. The settling and consolidation tests used to determine the filling rates, weir lengths, and initial storage volumes required to achieve the desired final surface elevations in the upland site proved successful. The field verification of the laboratory predictive tests was good in that the construction based on the test results produced the desired final surface elevations in the upland site.

Ground-water quality

73. Although ground-water quality was monitored during the FVP, techniques for predicting ground-water impacts from dredged material disposal are not developed and consequently were not evaluated.

Effluent quality

74. The quality of the effluent during the filling of the upland and wetland sites was predicted from the combined results of modified elutriate tests and column-settling tests. The reproducibility of the predictive method in the laboratory was good with standard deviations usually 25 to 50 percent of the mean for most parameters. Field verification of the predictions of effluent quality was good with laboratory predictions of most contaminant concentrations in the effluent being within a factor of 3 of the concentrations measured in the effluent from the field sites. The effluent quality prediction technique was good for predisposal evaluations of potential contaminant effects on effluent quality from upland and wetland creation sites.

Surface runoff quality

75. The mean concentrations of most contaminants predicted in surface runoff by laboratory tests were in fair agreement with the values observed in surface runoff tests conducted on the upland site after it was filled and had dried to typical upland conditions. Predicted values for some metals were within a factor of 2 to 3 of the concentrations observed in the field while for other metals, the laboratory and field data differed by a factor of almost 10. Organic contaminants in surface runoff were found to be below detection limits (Skogerboe et al. 1987). The procedure for evaluating surface runoff water quality showed fair utility for predisposal evaluations of proposed upland disposal of dredged material and for postdisposal monitoring of upland sites.

Upland plant toxicity

76. The reproducibility of the upland plant toxicity method was limited because survival of plants in the upland site was almost nonexistent. Laboratory predictions and field observations of plant survival agreed well. Even so, the utility of the technique for predisposal evaluation of toxicity to plants under upland disposal conditions was considered fair because the reproducibility and the exposure-response relationship are not clear. Vegetation was successfully established only on plots amended with lime plus horse manure, and lime plus sand plus gravel plus horse manure. Establishment of even salt-tolerant plant species on these plots was sparse and occurred primarily in cracks where the soil amendments were concentrated. All other plots were completely void of vegetation.

Bioaccumulation in upland plants

77. Reproducibility of the bioaccumulation test in the laboratory was limited because survival of plants in the upland site was almost nonexistent. The agreement between laboratory predictions of metals bioaccumulation and the bioaccumulation observed in the field was poor. Although predictions of bioaccumulation of one metal were fairly close, predictions for three metals were well above the values observed in the field, and predictions for two metals were well below observed values. At the present time, the variability in these predictions limits the utility of the upland plant bioaccumulation technique for predisposal evaluations. The method would be useful for monitoring of metals in plant tissues after disposal. In postdisposal monitoring applications, the purpose would be to quantitate the actual bioaccumulation of metals taking place on the site, and the predictive ability of the method would be of little concern. Bioaccumulation of organic contaminants in upland plants was not evaluated in the FVP.

Upland animal toxicity

78. Effects on earthworms of BRH dredged material under upland conditions were so great that the evaluations of the toxicity tests procedure could not be satisfactorily performed. The laboratory test predicted high and rapid mortality, which was observed in the field. However, the high salinity of the dried soil was a major contributor and interfered with the evaluation of the technique's ability to identify contaminant-related toxicity. Therefore, the utility of the upland animal toxicity test for predisposal evaluation of proposed upland disposal of highly contaminated, saline dredged material remains unknown, and research is necessary for further development of the technique.

Bioaccumulation in upland animals

79. Because of the poor survival of earthworms under upland conditions, techniques for predicting bioaccumulation could not be evaluated, and their utility remains unknown.

Techniques for Predicting Effects of Wetland Creation

Wetland site design

80. The settling and consolidation tests used to determine the filling rates, weir lengths, and initial storage volumes required to achieve the

desired final surface elevations in the wetland site proved successful. These tests have been used extensively elsewhere, and their reproducibility was not evaluated in the FVP. The field verification of the laboratory predictive tests was good in that the construction based on the test results produced the desired final surface elevations in the wetland site.

Wetland plant toxicity

81. The plant toxicity test in the wetland environment was not evaluated for its reproducibility or ability to indicate changes in toxicity related to changes in exposure to contaminants. The laboratory predictions of survival of *Spartina* were confirmed in the field, but laboratory results indicated *Sporobolus* would survive in the field, and it did not. Field verification of the technique for predicting survival of *Spartina* was good, and the method should be useful for predisposal evaluations of *Spartina* survival in wetland created with dredged material. However, the technique did not show correspondence between lab and field values for *Sporobolus*. It appears the overall utility of the technique is dependent upon the species to which it is applied; incomplete information on reproducibility limits the utility of the method. Further research is necessary if this technique is to be developed for routine use.

Bioaccumulation in wetland plants

82. Reproducibility of response and the ability to detect changing bioaccumulation in response to different contaminant exposures were not evaluated. The correspondence between laboratory predictions of metals bioaccumulation in *Spartina* and the metals concentrations observed in plants in the field was fair. Laboratory and field data for four of the six metals studied agreed within a factor of 4. For one metal, the laboratory value was approximately 0.01 of the field value. Because of this inconsistency and the lack of information on reproducibility, the wetland plant bioaccumulation technique can be considered to have fair utility for preconstruction evaluation of wetland creation with dredged material. However, for monitoring purposes, the technique seems useful because the predictive ability of the method would not be of concern in such applications. Bioaccumulation of organic contaminants by wetland plants was not evaluated in the FVP.

Wetland animal toxicity

83. The reproducibility of the test method was not evaluated. A relationship between toxicity and exposure to contaminants was indicated by the

absence of survival in static laboratory tests with pure BRH dredged material, but good survival in BRH dredged material was mixed 1:3 with clean sand. However, an exposure-response relationship was not clearly defined. The animals survived in recirculating laboratory tests, and the same species survived in the field, indicating fair field verification of the technique. The utility of the wetland animal toxicity test of predisposal evaluation is fair and requires additional research and development.

Bioaccumulation in wetland animals

84. The reproducibility of the test method and the ability of the method to detect changing bioaccumulation associated with different contaminant exposures were not evaluated for metals or organics. Laboratory predictions of metals bioaccumulation from the predredging BRH samples were field verified for four metals by comparing laboratory data on *Nereis virens* to field data on *Nereis succinea*, which naturally recolonized the wetland site. Because of the number of metals used, the different species, and the fact that the field data were three to eight times the laboratory data for three of the four metals, the field verification of the technique is considered poor. Although this indicates poor utility of the technique for preconstruction evaluations, the technique might be useful for monitoring where predictive ability is not of concern. Field verification of bioaccumulation of organics was considered fair. The laboratory and field data for PCB bioaccumulation in the two *Nereis* species were comparable, but for most PCB congeners examined, the laboratory data for *Nassarius* were two to eight times higher than the field data. Laboratory predictions of PAH bioaccumulation were not field verified. The utility of the wetland animal technique for preconstruction evaluations of bioaccumulation of organics is considered fair and requires additional research and development.

Techniques for Predicting Effects of Aquatic Disposal

Aquatic site design

85. The sampling methods and calculations used to determine dredged material volume destined for the aquatic disposal site proved reliable. The point dumping techniques were successful in that they resulted in a discrete, well-defined mound at the disposal point.

Toxicity

86. Tests of toxicity were reproducible in the laboratory in that repeated tests consistently showed good survival in 10 of the 11 test species representing 4 phyla. In one exception, the infaunal amphipod *Ampelisca abdita*, mortality was directly related to the proportion of BRH dredged material in the sediment. As time progressed, survival of many diverse species in the laboratory was paralleled by the recolonization by a wide range of species, including *A. abdita* at the disposal site. Laboratory toxicity tests simulating field exposure conditions have good utility for initial screening evaluations of dredged material.

SFG and bioenergetics

87. SFG in blue mussels *M. edulis* was reproducible and directly related to exposure to suspensions of BRH dredged material. There was good correspondence between laboratory and field SFG values in *M. edulis* when data collected under similar exposure conditions were compared. SFG in *M. edulis* has good utility for predisposal evaluations of dredged material proposed for aquatic disposal. The technique also has good utility for postdisposal monitoring purposes.

88. The bioenergetics measurements made on the polychaete *N. incisa* were also reproducible and correlated with exposure to BRH dredged material. At present, techniques for measuring bioenergetics in the field are limited to excretion and respiration, so only these aspects of bioenergetics could be field verified. The utility of the technique for predisposal evaluation is considered fair because only two aspects of bioenergetics could be field verified. These two measurements showed good correspondence between laboratory and field data. The utility of bioenergetics techniques for predisposal evaluations or postdisposal monitoring is fair.

AEC

89. Measurements of AEC in the laboratory were inconsistent and not clearly related to exposure to BRH dredged material. There was a semblance of comparability between laboratory and field results in that field responses were also erratic and minor. However, the utility of AEC for either predisposal evaluations or postdisposal monitoring of aquatic dredged material disposal is poor.

SCE

90. Measurements of SCE in the laboratory were not reproducible although there was some relationship to exposure to BRH dredged material. Because of the inconsistency of response, field verification was poor, and the utility of the procedure for predisposal or postdisposal evaluation is poor.

Histopathology

91. There was not a reproducible relationship in the laboratory between exposure to BRH dredged material and histopathological response. Field verification was fair in that minor, sporatic responses were seen in the laboratory, and occasional scattered incidences of minor abnormalities were seen in the field. In the FVP, histopathology showed poor utility in predisposal evaluation of dredged material proposed for aquatic disposal. In concept, histopathology could be very useful for long-term monitoring where the duration of exposure would allow for the possible induction and manifestation of histologic changes.

Population growth rates

92. Growth, reproduction, and intrinsic rate of population growth were reproducible and related to exposure to BRH dredged material in the laboratory. Based on the consistency of response in the laboratory, the ability to detect effects at low exposure conditions typical of the field, and the environmental importance of the biological endpoints being measured, these techniques are considered to have good utility for predisposal evaluations of dredged material proposed for aquatic disposal. However, population growth rates were not field verified in this study because the techniques to calculate rates from field data require further research and development.

Bioaccumulation

93. Bioaccumulation of metals and organics in the laboratory was very reproducible and was correlated with exposure to BRH dredged material. When bioaccumulation data collected under the same exposure conditions in the laboratory and field are compared, field verification of the technique is good. The utility of bioaccumulation for both predisposal evaluations and postdisposal monitoring of dredged material in the aquatic environment is good.

PART VIII: COMPARISON OF EFFECTS OF DREDGED MATERIAL PLACEMENT IN UPLAND, WETLAND, AND AQUATIC ENVIRONMENTS

94. The FVP examined one or more effects of dredged material disposal on a total of three species in the upland environment, six species in the wetland environment, and twelve species in the aquatic environment; the program also evaluated the entire community recolonizing the aquatic disposal site. Seven major potential impacts were examined in upland disposal; four in wetland creation; and eight in aquatic disposal. In each of three disposal environments, bioaccumulation of approximately a dozen or more metals, PAHs, and PCB congeners was measured. The program constitutes the most comprehensive examination of dredged material impacts in different environments ever undertaken. It is also unique in that it is the only instance in which effects of the same material in three disposal environments were compared.

95. Detailed quantitative comparison of effects in upland, wetland, and aquatic environments is not possible in such a comprehensive study because of a lack of commonality among the ecologies of the different disposal environments. However, qualitative findings of the FVP in terms of effects in different disposal environments can be summarized in a few general observations:

a. Effects tended to be more severe in the upland environment than in the wetland or aquatic environments. This is particularly true when the almost total mortality of some upland species is compared to the generally low incidence of sublethal responses in the aquatic environment under actual exposure conditions.

b. At the end of the 6-year program, some plant and animal species still were not established on the upland and wetland sites. Community studies at the aquatic site showed rapid recolonization by a variety of species to a benthic community typical of Central Long Island Sound with few indications of serious long-term impacts.

c. The proportion of the species examined that showed substantial effects was much greater in the upland environment than in the wetland and aquatic environments. The detrimental effects of upland disposal were certainly influenced by the presence of environmental contaminants as well as the very high salinity typical of estuarine sediments dried in upland environments.

d. Prior to the FVP, techniques for evaluating dredged material disposal in the aquatic environment had received more developmental effort for a longer time then upland or wetland evaluative techniques. Therefore, more techniques are available for aquatic disposal evaluation than for upland or wetland evaluation. The techniques available for evaluating upland and wetland effects on plant and animals emphasize mortality and

bioaccumulation. Aquatic techniques tend to emphasize chronic, sublethal effects in addition to mortality and bioaccumulation. Therefore, in the FVP more sublethal effects were measured in the aquatic environment than in the upland or wetland environments.

e. Techniques for managing upland disposal sites to establish vegetative cover proved successful. Laboratory and field data indicated the use of salt-tolerant plant species, and extensive efforts to control soil texture, acidity, and free metals using sand, lime, and manure would be required. These data proved effective in the field.

f. The techniques for evaluating water quality effects of upland and wetland sites during site filling (effluent evaluations) and site operation (surface runoff evaluation) were useful predictive tools.

g. BRH dredged material has had a greater and more persistent impact in the upland environment than in the wetland environment, and impacts in the aquatic environment have been the least severe and least persistent. Because the underlying physicochemical characteristics that distinguish upland, wetland, and aquatic dredged material sites are consistent wherever such sites occur, there is no reason to expect the three environments to rank differently in overall degree of impact from other dredged material. However, relative magnitude of effect could differ with different dredged material.

PART IX: CONCLUSIONS

96. The Field Verification Program has demonstrated that the environmental effects of contaminated dredged material are greatly influenced by the physicochemical environment in which the material is placed. Aquatic disposal, which results in the fewest physicochemical changes, produced the lease severe and least persistent impacts while upland disposal, which results in the most physicochemical changes, produced the greatest and most persistent impacts. Wetland creation, which usually resembles aquatic disposal more than upland disposal from a physicochemical perspective, resulted in fewer impacts than upland disposal but in more impacts than aquatic disposal.

97. Techniques for predicting effluent and surface water quality and plant toxicity associated with upland disposal were verified by field studies. The effluent and surface water quality evaluation techniques were also shown to have good utility for predisposal evaluation of dredged material disposal in the upland environment. While the wetland plant bioassay tests have their optimum utility for preconstruction evaluation of wetland creation, the animal bioassay tests await confirmation of their reproducibility and ability to detect different responses to different contaminant exposures. Both SFG and bioaccumulation show good field verification of laboratory results in the aquatic environment and have good utility for predisposal evaluation of dredged material proposed for aquatic disposal. Laboratory toxicity tests mirrored the generally rapid and normal recolonization observed at the aquatic disposal site. Laboratory determinations of population dynamics are sensitive and ecologically relevant. Techniques to field verify these laboratory determinations await further research and development. Both of these techniques have good utility for predisposal evaluations of proposed aquatic disposal of dredged material. Several other techniques appropriate to each of the disposal environments have promise and are being refined to enhance their utility.

REFERENCES

Folsom, B. L., Jr., et al. "Synthesis of the Results of the Field Verification Program Upland Disposal Alternative," Technical Report (in preparation), US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Folsom, B. L., Jr., and Lee, C. R. 1981. "Development of a Plant Bioassay for Determining Toxic Metal Uptake From Dredged and/or Fill Material," Proceedings-International Conference, Heavy Metals in the Environment, Amsterdam, The Netherlands pp 417-420.

_________. 1982. "On the Adequacy of Mixing Large Volumes of Sediment," Agronomy Abstracts, 1982 Annual Meetings, Anaheim, CA.

Francingues, N. R., Palermo, M. R., Lee, C. R., and Peddicord, R. K. 1985. "Management Strategy for Disposal of Dredged Material: Test Protocols and Contaminant Control Measures," Miscellaneous Paper D-85-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Gentile, J. H., et al. 1988. "Synthesis of Research Results: Applicability and Field Verification of Predictive Methodologies for Aquatic Dredged Material Disposal," Technical Report D-88-5, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Gentile, J. H., Scott, J. K., Lussier, S., and Redmond, M. S. 1985. "Applications of Population Responses for Evaluating the Effects of Dredged Material," Technical Report D-84-8, prepared by the US Environmental Protection Agency, Environmental Research Laboratory, Narragansett, RI, for the US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Johns, D. M., Gutjahr-Gobell, R., and Schauer, P. 1985. "Use of Bioenergetics to Investigate the Impact of Dredged Material on Benthic Species: A Laboratory Study with Polychaetes and Black Rock Harbor Material," Technical Report D-85-7, prepared by US Environmental Research Laboratory, Narragansett, RI, for the US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lake, J. L., Hoffman, G. L., and Schimmel, S. E. 1985. "The Bioaccumulation of Contaminants from Black Rock Harbor Material by Mussels and Polychaetes," Technical Report D-85-2, prepared by the US Environmental Protection Agency, Environmental Research Laboratory, Narragansett, RI, for the US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lee, C. R., Folsom, B. L., Jr., and Bates, D. J. 1983. "Prediction of Plant Uptake of Toxic Metals Using a Modified DTPA Extraction," The Science of the Total Environment, Vol 28, pp 191-202.

Lee, C. R., and Skogerboe, J. G. 1984. "Restoration of Pyritic Soils and the Quantification of Erosion Control," Miscellaneous Paper EL-84-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Morton, R. W. 1983. "Status Report: Disposal Operations at the Central Long Island Sound Disposal Site," DAMOS Contribution 25, prepared by Science Applications, Inc. for the US Army Corps of Engineers, New England Division, Waltham, MA.

Nelson, W. G., et al. 1987. "Effects of Black Rock Harbor Dredged Material on the Scope for Growth of the Blue Mussel, *Mytilus edulis*, After Laboratory and Field Exposures," Technical Report D-87-7, prepared by the US Environmental Protection Agency, Narragansett, RI, for the US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Palermo, M. R. 1985. "Interim Guidance for Predicting the Quality of Effluent from Dredged Material Disposal Areas," Environmental Effects of Dredging Technical Notes EEDP-04-1 through 04-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS. Also published as Miscellaneous Paper D-86-1.

Palermo, M. R., Montgomery, R. L., and Poindexter, M. 1978. "Guidelines for Designing, Operating, and Managing Dredged Material Containment Areas," Technical Report DS-78-10, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Pesch, G. G., et al. 1987. "Sister Chromatid Exchange in Marine Polychaetes Exposed to Black Rock Harbor Sediment," Technical Report D-87-5, prepared by the US Environmental Protection Agency, Narragansett, RI, for the US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Rogerson, P. F., Schimmel, S. C., and Hoffman, G. 1985. "Chemical and Biological Characterization of Black Rock Harbor Dredged Material," Technical Report D-85-9, prepared by the US Environmental Protection Agency, Narragansett, RI, for the US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Saucier, R. T., Calhoun, C. C., Engler, R. M., Patin, T. R., and Smith, H. K. 1978. "Dredged Material Research Program: Executive Overview and Detailed Summary," Technical Report DS-78-22, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Scott, K. J., et al. 1987. "The Impact of Open Water Disposal of Black Rock Harbor Dredged Material on Benthic Recolonization at the FVP Site," Technical Report D-87-4, prepared by the US Environmental Protection Agency, Narragansett, RI, for the US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Simmers, J. W., Folsom, B. L., Jr., Lee, C. R., and Bates, D. J. 1981. "Field Survey of Heavy Metal Uptake by Naturally Occurring Saltwater and Freshwater Marsh Plants," Technical Report EL-81-5, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Simmers, J. W., et al. "Synthesis of the Results of the Field Verification Program Wetland Disposal Alternative," Technical Report (in preparation), US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Skogerboe, J. G., et al. 1987. "Prediction of Surface Runoff Water Quality from Black Rock Harbor Dredged Material Placed in an Upland Disposal Site," Miscellaneous Paper D-87-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A182 235.

Yevich, P. P., et al. 1986. "Histopathological Effects of Black Rock Harbor Dredged Material on Marine Organisms; A Laboratory Investigation," Technical Report D-86-1, prepared by US Environmental Protection Agency, Environmental Research Laboratory, Narragansett, RI, for the US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Zaroogian, G. E., et al. 1985. "Laboratory Evaluation of Adenylate Energy Charge as a Test for Stress in *Mytilus edulis* and *Nephyts incisa* Treated with Dredged Material," Technical Report D-85-3, prepared by US Environmental Protection Agency, Narragansett, RI, for the US Army Engineer Waterways Experiment Station, Vicksburg, MS.

APPENDIX A: CITATIONS FOR ALL FIELD VERIFICATION PROGRAM REPORTS

Synthesis Reports

Folsom, B. L., Jr., et al. "Synthesis of the Results of the Field Verification Program Upland Disposal Alternative," Technical Report (in preparation) US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Gentile, J. H., et al. 1988. "Applicability and Field Verification of Predictive Methodologies for Aquatic Dredged Material Disposal," Technical Report D-88-5, prepared by the US Environmental Protection Agency, Narragansett, RI, for the US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Simmers, J. W., et al. "Synthesis of the Results of the Field Verification Program Wetland Disposal Alternative," Technical Report (in preparation), US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Individual Technical Support Documents

Folsom, B. L., Jr. 1987. "Field Verification of the Estuarine Plant Bioassay Procedure," Technical Note EEDP-03-3, Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Folsom, B. L., Jr., and Lee, C. R. 1985. "Plant Bioassay of Dredged Material," Technical Note EEDP-01-1, Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Gentile, J. H., et al. 1985. "Application of Laboratory Population Responses for Evaluating the Effects of Dredged Material," Technical Report D-85-8, Environmental Research Laboratory, US Environmental Protection Agency, Narragansett, RI, prepared for the Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

__________. 1987. "The Assessment of Black Rock Harbor Dredged Material Impacts on Laboratory Population Responses," Technical Report D-87-3, Environmental Research Laboratory, US Environmental Protection Agency, Narragansett, RI, prepared for Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

__________. 1988. "Applicability and Field Verification of Predictive Methodologies for Aquatic Dredged Material Disposal," Technical Report D-88-5, Environmental Research Laboratory, US Environmental Protection Agency, Narragansett, RI, prepared for Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Johns, D. M., and Gutjahr-Gobell, R. 1988. "Bioenergetic Effects of Black Rock Harbor Dredged Material on the Polychaete *Nephtys incisa*: A Field Verification," Technical Report D-88-3, Environmental Research Laboratory, US Environmental Protection Agency, Narragansett, RI, prepared for Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Johns, D. M., Gutjahr-Gobell, R., and Schauer, P. 1985. "Use of Bioenergetics to Investigate the Impact of Dredged Material on Benthic Species: A Laboratory Study with Polychaetes and Black Rock Harbor Material," Technical Report D-85-7, Edgerton Research Laboratory, Boston, MA, and Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A161 050.

Lake, J. L., et al. "Comparisons of Field and Laboratory Bioaccumulation of Organic and Inorganic Contaminants for BRH Dredged Material," Technical Report (in preparation), Environmental Research Laboratory, US Environmental Protection Agency, Narragansett, RI, prepared for Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Lake, J., Hoffman, G. L., and Schimmel, S. C. 1985. "Bioaccumulation of Contaminants from Black Rock Harbor Dredged Material by Mussels and Polychaetes," Technical Report D-85-2, Environmental Research Laboratory, US Environmental Protection Agency, Narragansett, RI, prepared for the Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A157 365.

Nelson, W. G., Black, D., and Phelps, D. 1985. "Utility of the Scope for Growth Index to Assess the Physiological Impact of Black Rock Harbor Suspended Sediment on the Blue Mussel, *Mytilus edulis*: A Laboratory Evaluation," Technical Report D-85-6, Environmental Research Laboratory, US Environmental Protection Agency, Narragansett, RI, prepared for the Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A161 056.

Nelson, W. G., et al. 1987. "Effects of BRH Dredged Material on the Scope of Growth of the Blue Mussel *Mytilus edulis* After Laboratory and Field Exposures," Technical Report D-87-7, Environmental Research Laboratory, US Environmental Protection Agency, Narragansett, RI, prepared for Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Palermo, M. R. "Field Verification Program: Containment Area Effluent Quality Field Results," Engineer Technical Letter (in preparation), US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Palermo, M. R., and Pranger, S. "Field Verification Program: Upland/Wetland Site Design, Construction and Operation," Engineer Technical Letter (in preparation), US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Pesch, G. G., et al. 1987. "Sister Chromatid Exchange in Marine Polychaetes Exposed to Black Rock Harbor Sediment," Technical Report D-87-5, US Environmental Protection Agency, Narragansett, RI, prepared for Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Pesch, G. G., Mueller, C., Pesch, C. E., Heltshe, J., and Schauer, P. S. 1985. "Application of Sister Chromatid Exchange in Marine Polychaetes to Black Rock Harbor Sediment, Laboratory Documentation Phase," Technical Report D-85-1, Environmental Research Laboratory, US Environmental Protection Agency, Narragansett, RI, prepared for the Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A157 372.

Rogerson, P. F., Schimmel, S. C., and Hoffman, G. 1985. "Chemical and Biological Characterization of Black Rock Harbor Dredged Material," Technical Report D-85-9, Environmental Research Laboratory, US Environmental Protection Agency, Narragansett, RI, prepared for the Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A164 065.

Scott, J., et al. 1987. "Impact of Open-Water Disposal of Black Rock Harbor Dredged Material on Benthic Recolonization at the FVP Site," Technical Report D-87-4, US Environmental Protection Agency, Narragansett, RI, prepared for the Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Sheng, P. Y. 1984. "Preliminary User's Manual 3-D Mathematical Model of Coastal, Estuarine, and Lake Currents (CELC3D)," Instruction Report D-84-1, Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A142 070.

Skogerboe, J. G., et al. 1987. "Prediction of Surface Runoff Water Quality from Black Rock Harbor Dredged Material Placed in an Upland Disposal Site," Miscellaneous Paper D-87-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A182 235.

Skogerboe, J. G., and Lee, C. R. 1987. "Upland Disposal Site Management of Surface Runoff Water Quality," Technical Note EEDP-02-3, Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Simmers, J. W. 1986. "Upland Animal Bioassays of Dredged Material," Technical Note EEDP-0202, Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Simmers, J. W., et al. 1987. "Wetland Animal Bioassay/Biomonitoring," Technical Note EEDP-03-2, Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

__________. 1987. "Upland Animal Bioassay of Dredged Material," Technical Note EEDP-04, Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Simmers, J. W., Rhett, R. G., and Lee, C. R. 1986. "Wetland Animal Bioassay of Saltwater Dredged Material," Technical Note EEDP-03-1, Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Yevich, P. P., et al. 1987. "The Effects of Black Rock Harbor Dredged Material on the Histopathology of the Blue Mussel *Mytilus edulis* and Polychaete Worm *Nephtys incisa* After Laboratory and Field Exposures," Technical Report D-87-8, Environmental Research Laboratory, US Environmental Protection Agency, Narragansett, RI, prepared for the Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

__________. 1986. "Histopathological Effects of Black Rock Harbor Dredged Material on Marine Organisms, A Laboratory Investigation," Technical Report D-86-1, Environmental Research Laboratory, Narragansett, RI, prepared for the Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A168 126.

Zaroogian, G. E., et al. 1988. "A Field and Laboratory Study Using Adenylate Energy Charge as an Indication of Stress in *Mytilus edulis* and *Nephtys incisa* Treated with Dredged Material," Technical Report D-88-4, Environmental Research Laboratory, US Environmental Protection Agency, Narragansett, RI, prepared for Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Zaroogian, G. E., Pesch, C., Schauer, P., and Black, D. 1985. "Laboratory Evaluation of Adenylate Energy Charge as a Test for Stress in *Mytilus edulis* and *Nephtys incisa* Treated with "Dredged Material," Technical Report D-85-3, Environmental Research Laboratory, US Environmental Protection Agency, Narragansett, RI, prepared for the Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS. NTIS No. AD A157 374.